NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 199

INTERFERENCE TESTS ON AN N. A. C. A. PITOT TUBE

By ELLIOTT G. REID

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AERONAUTICAL SYMBOLS.

1. FUNDAMENTAL AND DERIVED UNITS.

	Symbol.	Metric.		English.	
		Unit.	Symbol.	Unit.	Symbol.
Length	l	meter	m.	foot (or mile)	ft. (or mi.).
Time	t	second	sec.	second (or hour)	sec. (or hr.).
Force	F	weight of one kilogram	kg.	weight of one pound	lb.
Power	P	kg.m/sec		horsepower	HP
Speed		m/sec	m. p. s.	mi/hr	M. P. H.

2. GENERAL SYMBOLS, ETC.

Weight, $W=mg$.

Standard acceleration of gravity, $g=9.806\text{m/sec.}^2=32.172\text{ft/sec.}^2$

Mass, $m=\frac{W}{g}$

Density (mass per unit volume), ρ

Standard density of dry air, 0.1247 (kg.-m.-sec.) at 15.6°C. and 760 mm. = 0.00237 (lb.-ft.-sec.)

Specific weight of "standard" air, 1.223 kg/m.^{3} = 0.07635 lb/ft.^{3}

Moment of inertia, mk^2 (indicate axis of the radius of gyration, k, by proper subscript).

Area, S; wing area, S_w, etc.

Gap, G

Span, b; chord length, c.

Aspect ratio $=b/c$

Distance from $c.\ g.$ to elevator hinge, f.

Coefficient of viscosity, μ.

3. AERODYNAMICAL SYMBOLS.

True airspeed, V

Dynamic (or impact) pressure, $q=\frac{1}{2}\rho V^2$

Lift, L; absolute coefficient $C_L=\frac{L}{qS}$

Drag, D; absolute coefficient $C_D=\frac{D}{qS}$.

Cross-wind force, C; absolute coefficient

$$C_c=\frac{C}{qS}.$$

Resultant force, R

(Note that these coefficients are twice as large as the old coefficients L_c, D_c.)

Angle of setting of wings (relative to thrust line), i_w

Angle of stabilizer setting with reference to thrust line i_t

Dihedral angle, γ

Reynolds Number $=\rho\frac{Vl}{\mu}$, where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi/hr., normal pressure, 0°C: 255,000 and at 15.6°C, 230,000;

or for a model of 10 cm. chord, 40 m/sec., corresponding numbers are 299,000 and 270,000.

Center of pressure coefficient (ratio of distance of C. P. from leading edge to chord length), C_p.

Angle of stabilizer setting with reference to lower wing. $(i_t-i_w)=\beta$

Angle of attack, α

Angle of downwash, ϵ

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INTERFERENCE TESTS

ON AN N. A. C. A. PITOT TUBE

By Elliott G. Reid

INTRODUCTION

Because of the universally felt uncertainty of air-speed measurements by the Pitot tube, when the instrument is mounted close to some other body—as is so frequently the case in both flight and tunnel research—a series of tests have been made in the No. 1 (5-ft. atmospheric) wind tunnel of the National Advisory Committee for Aeronautics with the object of determining the nature and magnitude of errors inherent to some of the most common installations.

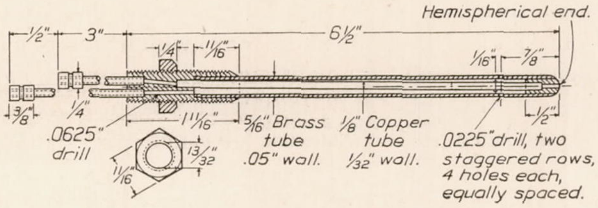

Fig. 1.—Pitot static tube used in tests

APPARATUS AND PROCEDURE

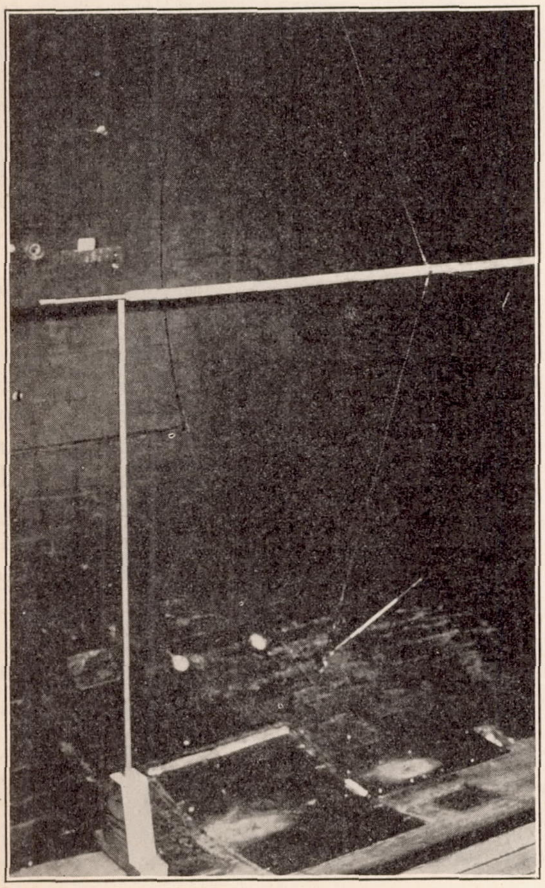

Fig. 2.—General view of set-up. Perpendicular rod in place for interference tests

The Pitot-static tube used throughout these tests was of the type developed and generally used at Langley Memorial Laboratory; details of construction are shown in Figure 1.

The tunnel installation may be seen in Figure 2, which illustrates the first interference investigated. As shown in this photograph, the Pitot was screwed into the end of a 5-ft. (152.4 cm.) length of 1/4 in. (1.37 cm.O.D.) pipe and the latter supported axially in the tunnel by a number of wires, the farthest upstream point of support being 2-ft. (60.96 cm.) behind the nose of the tube. Rubber tubes were led from the Pitot through the pipe to its downstream end, along one of the supporting wires to the tunnel wall, and thence to an alcohol-filled micromanometer.[1]

The end of the pipe was chamfered and the addition of a little wax made its juncture with the Pitot tube quite smooth. This set-up located the front end of the instrument 40 in. (101.6 cm.) downstream from the fine honeycomb (3/8 x 3 in.) (0.95 x 7.62 cm.) tubes.

A calibration run against the Pitot ordinarily used for tunnel air-speed measurement gave a dead check, except at one point, with a previous calibration in which a standard N. P. L. tube had been used in the same position. At a speed of 5 m/s (16.4 ft./sec.), the error in head was 0.1 mm. (0.004 in.), the least count of the manometer vernier.

[1] A complete description of this instrument appears in N. A. C. A. Technical Note No. 81. The least count of the vernier is 0.1 mm.

The first test simulated the conditions prevailing in the use of the N. P. L. (right angle) type Pitot. The set-up is shown in Figure 2. The cylindrical rod, of the diameter of the Pitot tube, was supported in a block which was fastened to the tunnel wall and its other end was in contact with the tube, or the pipe, as it was moved downstream. Starting close behind the static orifices, the rod was moved downstream until the observed Pitot-static difference became negligibly different from that found with no interference. Readings were made at three air speeds, 10, 20, and 30 m/s (32.8, 65.6, and 98.4 ft./sec.), at each position to detect the existence of any scale effect. Although only the Pitot-static differences $(h_s+h_q)-h_s=q/\delta$, where δ is the density of the manometer fluid, appear in the data, the impact tube reading was observed separately and it was found that no variation could be detected for any of the conditions encountered.

The second case investigated was one having its application in the method used here for the exploration of wind tunnels for velocity distribution. The Pitot tube was set into a rectangular bar ¾ x 1½ in. (1.91 x 3.81 cm.) which was placed as a tunnel throat diameter, the narrow face being presented to the airflow. The upstream side of the bar was 4½ in. behind the static openings of the tube and data were taken at 20 and 30 m/s (65.6 and 98.4 ft./sec.). As 4½ in. (11.43 cm.) is the greatest distance that can be obtained with the standard tube, unless an

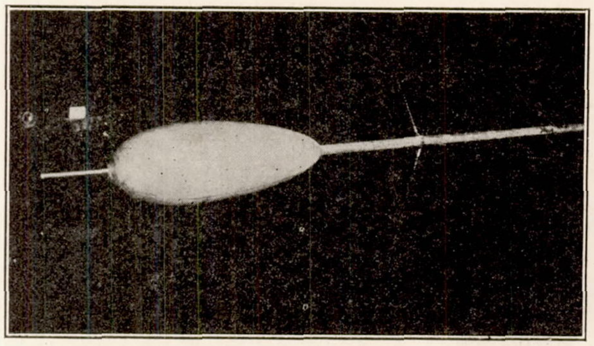

FIG. 3.—Installation for test on interference of streamline body.

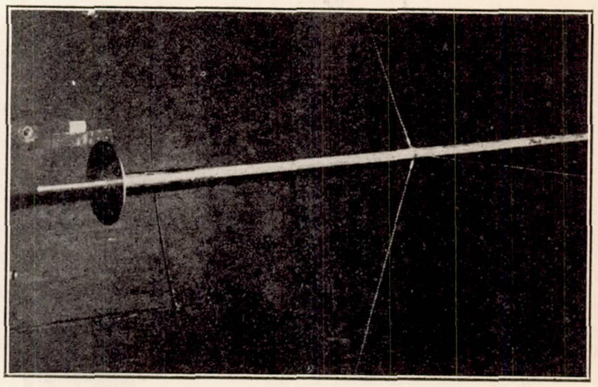

FIG. 4.—Installation for test on interference of disk

extension be used, no attempt was made to find the shape of the interference curve and the two point values constitute all the data.

The interference condition of case three is particularly applicable to trailing flight test instruments, although it gives valuable indications on streamline forms in general. A split body of revolution, evolved from a Joukowski airfoil profile of length-thickness ratio 4.5 by simply fairing it to a blunt end at about 0.7 the original length, was clamped on the pipe in several positions behind the Pitot (see fig. 3) and data similar to that of the first case observed.

The process was repeated for the fourth case, in which a disk of the same diameter as that of the maximum section of the streamline body was used. This set-up is shown in Figure 4. This test was begun with the object of providing a base for comparison but the data showed the existence of a very peculiar state of affairs which indicated that the disk and Pitot tube might prove valuable as a "turbulence meter".

Accordingly, a fifth test was made. It differed from the fourth only in that a wire screen of ¼ in. (0.635 cm.) mesh was placed 9 in. (22.86 cm.) upstream from the nose of the tube.

RESULTS AND DISCUSSION

The calibration data are contained in Table I; Figure 10 is plotted therefrom. The slope of the calibration curve is exactly one.

Table II contains the data relating to the interference of a cylindrical rod. To facilitate comparison, the recorded heads have been reduced to percentages of the heads existing under conditions of no interference. These values have been plotted against distance aft of the static

orifices of the Pitot tube as Figure 5. The curves show the existence of a considerable scale effect, as might be expected from the shape of the resistance coefficient curve for cylinders in that Vl range, and there is, also, indication of a critical interference at about 3 inches distance with the two lower speeds. As the rod was very close to the juncture of Pitot tube and pipe, at this distance, little concern is felt over the apparent reversal of the interference curves; as

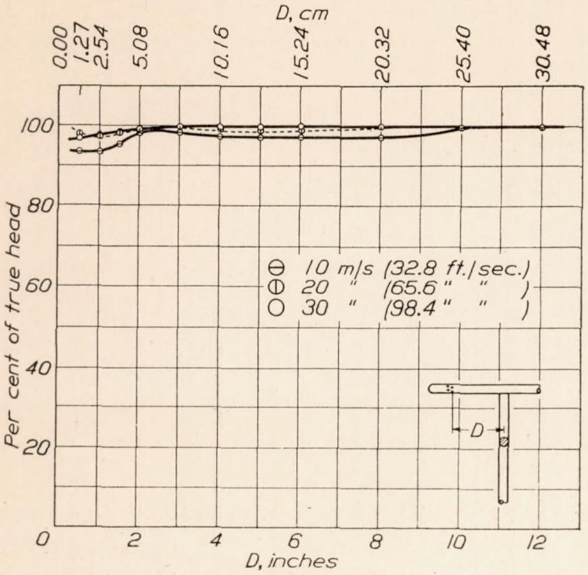

FIG. 5

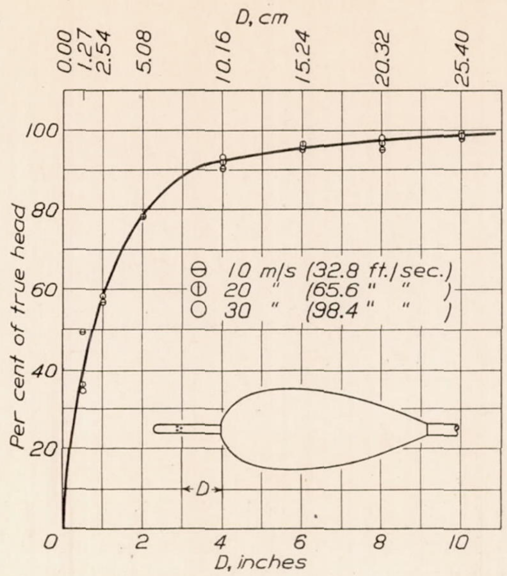

FIG. 6

the reversal does not appear in the data from the high speed run, the effect is attributed to the slight form irregularity. The maximum error in head found under these conditions being only 6.5% (3.4% in velocity), the interference curves have not been plotted on abscissae of rod diameter units but, if we agree to neglect the reflex portions of the curves, the results indicate that 1% accuracy may be had if the perpendicular cylinder be kept eight or more diameters behind the static orifices.

The data in Table III require little comment; it is indicated that mounting Pitot tubes on a rectangular bar of the proportions used here will give rise to an error of roughly 6% in head or 3% in velocity. In connection with this type of interference it would be valuable to know the relative magnitude of errors which would be produced by the substitution of a strut of sufficient size to enclose the bar.

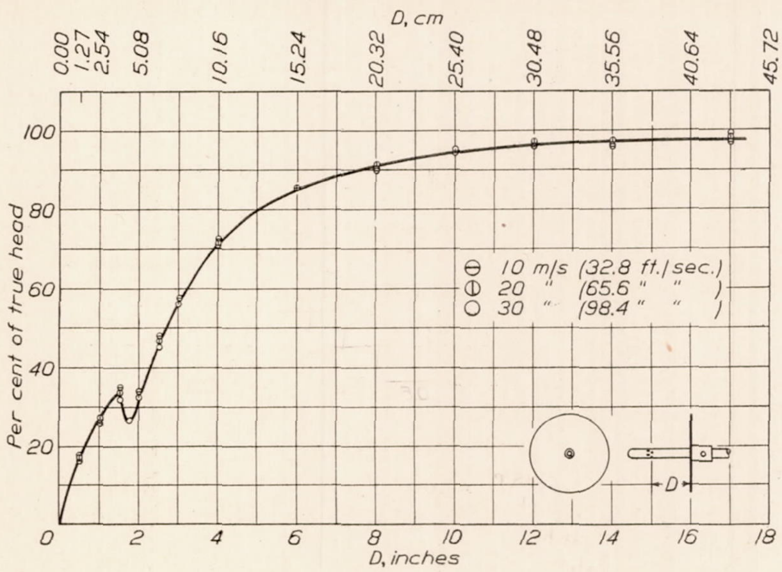

FIG. 7

When the size of the stream-line body is considered, its interference seems remarkably small. The data from the tests of this section are tabulated in Table IV and plotted in Figure 6. It is worthy of note that scale effect is entirely absent except when the nose of the body is very close to the static openings of the tube.

In Table V are contained the data on the interference of a disk having the same diameter as that of the stream-line body at its maximum section. Figure 7 brings out two interesting points in addition to depicting the interference effect. In accordance with expectation, scale

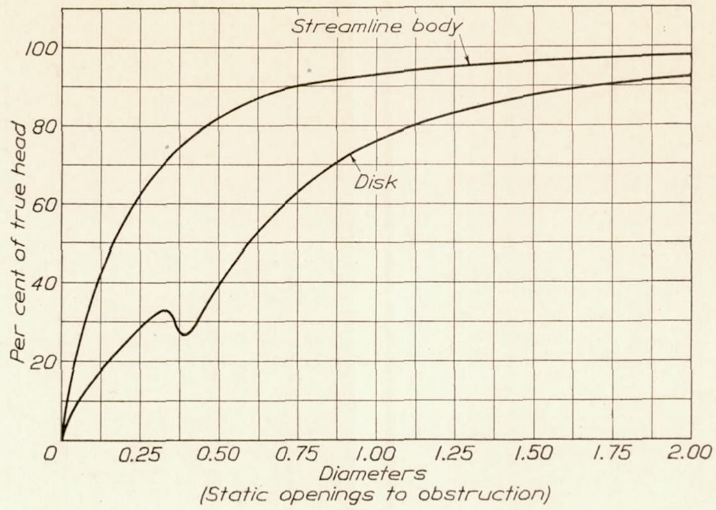

FIG. 8

effect is conspicuous by its absence, and the interference curve has an unexpected double inflection at a small distance behind the active portion of the tube. This sharply defined irregularity suggested the possibility of using the combination of disk and tube as a "turbu-

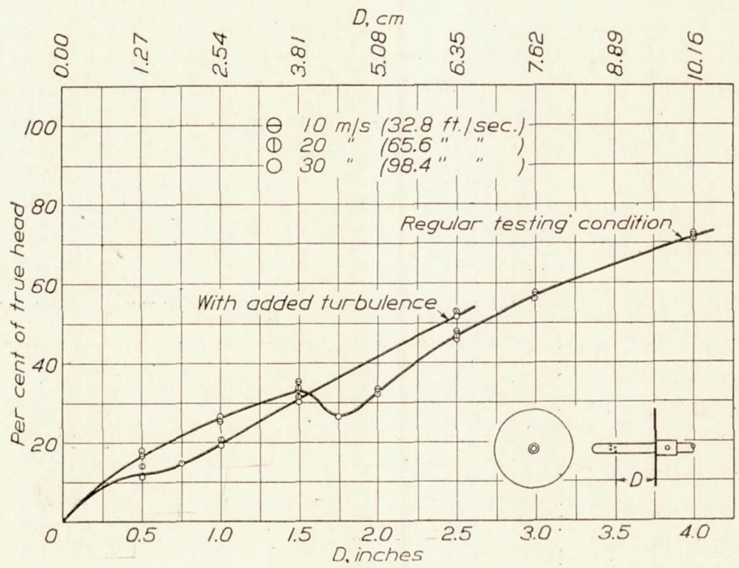

FIG. 9

lence meter." This curve and the one of Figure 6 have been replotted in Figure 8, the abscissa unit there being the diameter of the interfering body; the difference in interference of disk and stream-line body here becomes very apparent.

Results obtained from the Pitot-disk combination under conditions of increased turbulence are given in Table VI, from which Figure 9 is plotted. It will be seen that in this airflow the critical interference occurs with the disk much closer to the static orifices than was the case in the previous test, and that the break in the curve is much less acute. It is believed that the break will occur at a distance which is, for any given condition of turbulence, a fixed proportion of the disk diameter. The indication is, of course, that in a smooth air flow this point is the upstream limit of the turbulent mass of air in front of the disk and that, as the

turbulence increases, the point will move toward the face of the disk and become less distinct. It is planned to extend this phase of the work and, if possible, evolve a practical "turbulence meter."

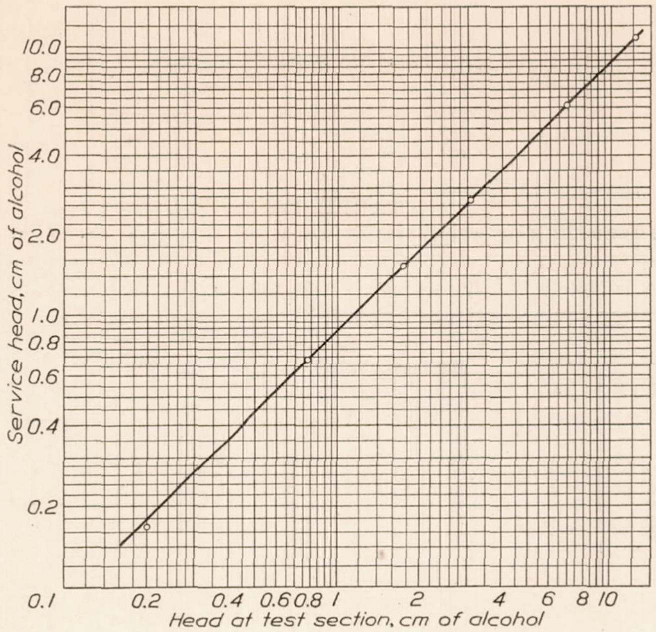

FIG. 10

TABLE I

CALIBRATION OF N. A. C. A. PITOT-STATIC TUBES

V	h_1	h_2
(m/s)	Head (cm. alcohol)	
5	0.17	0.20
10	.69	.77
15	1.55	1.73
20	2.72	3.05
30	6.09	6.86
40	10.75	12.23

h_1 = Pitot-static head indicated by calibrated service instrument.
h_2 = Pitot-static head indicated by instrument under test.

TABLE II

INTERFERENCE OF 3/8" (0.95 cm.) ROD PERPENDICULAR TO N. A. C. A. PITOT TUBE

V (m/s)		10	20	30	10	20	30
D		Head (cm. alcohol)			%h		
(cm.)	in.						
1.27	½	0.72	2.99	6.65	93.5	98.1	97
2.54	1	.72	2.97	6.70	93.5	97.4	97.7
3.81	1½	.74	2.99	6.77	94.8	98.1	98.7
5.08	2	.76	3.02	6.81	98.7	99	99.3
7.62	3	.76	3.04	6.84	98.7	99.7	99.7
10.16	4	.75	3.03	6.85	97.4	99.4	99.8
12.70	5	.75	3.02	6.85	97.4	99	99.8
15.24	6	.75	3.02	6.86	97.4	99	100
20.32	8	.75	3.05	6.85	97.4	100	99.8
25.40	10	.77	3.04	6.86	100	99.7	100
30.48	12	.77	3.04	6.86	100	99.7	100
∞	∞	.77	3.05	6.86	----------	----------	----------

D = Distance from static openings to center line of 3/8 in. (0.95 cm.) rod.

TABLE III

INTERFERENCE OF ¾″ x 1½″ (1.91 x 3.81 cm) BAR 4½″ (11.43 cm.) BEHIND STATIC OPENINGS OF N. A. C. A. PITOT TUBE

V (m/s)		20	30	20	30
D		Head (cm. alcohol)		%h	
(cm.)	in.				
11.43	4½	2.86	6.46	94	94
∞	∞	3.04	6.87		

TABLE IV

INTERFERENCE OF STREAMLINE BODY ON N. A. C. A. PITOT TUBE

V (m/s)		10	20	30	10	20	30
D		Head (cm. alcohol)			%h		
(cm.)	in.						
1.27	½	0.38	1.08	2.40	49.4	35.4	34.9
2.54	1	.44	1.77	4.00	57.2	58.0	58.2
5.08	2	.60	2.43	5.48	78.0	78.1	78.3
10.16	4	.70	2.82	6.38	91.0	92.4	92.9
15.24	6	.73	2.94	6.57	95.0	96.4	95.7
20.32	8	.73	2.95	6.73	95.0	96.7	98.0
25.40	10	.75	2.97	6.82	97.5	97.4	99.3
∞	∞	.77	3.05	6.86			

D=Distance from static openings to nose of body.

TABLE V

INTERFERENCE OF 4½″ (11.43 cm.) DISK ON N. A. C. A. PITOT TUBE

V (m/s)		10	20	30	10	20	30
D		Head (cm. alcohol)			%h		
(cm.)	in.						
1.27	½	0.13	0.53	1.22	16.9	17.4	17.8
2.54	1	.20	.82	1.82	26.0	26.9	26.5
3.81	1½	.27	1.03	2.20	35.1	33.8	32.1
4.45	1¾			1.82			26.5
5.08	2	.26	1.01	2.25	33.8	33.1	32.8
6.35	2½	.37	1.43	3.16	48.0	46.9	46.1
7.62	3	.44	1.71	3.85	57.1	56.1	56.1
10.16	4	.56	2.17	4.89	72.7	71.2	71.3
15.24	6	.66	2.60	5.89	85.7	85.3	85.8
20.32	8	.70	2.79	6.26	90.9	91.5	91.2
25.40	10	.73	2.91	6.55	94.8	95.4	95.5
30.48	12	.74	2.97	6.64	96.1	97.4	96.8
35.56	14	.74	2.98	6.67	96.1	97.7	97.2
43.18	17	.75	3.01	6.80	97.4	98.7	99.1
∞	∞	.77	3.05	6.86			

D=distance from static openings to disk.
Turbulence: regular testing condition.

TABLE VI

INTERFERENCE OF 4½″ (11.43 cm.) DISK ON N. A. C. A. PITOT TUBE

V (m/s)		20	30	20	30
D		Head (cm. alcohol)		%h	
(cm.)	in.				
1.27	½	0.43	0.77	14.1	11.2
1.91	¾	.45	.98	14.7	14.3
2.54	1.00	.63	1.33	20.6	19.4
3.81	½	.96	2.08	31.5	30.3
6.35	2½	1.61	3.52	52.8	51.4
∞	∞	3.05	6.86		

D=distance from static openings to disk.
Turbulence: Wire screen, ¼ in. (0.635 cm.) mesh, 9 in. (22.86 cm.) upstream from tube.

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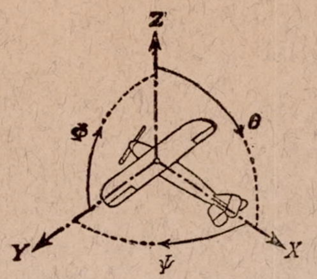

Positive directions of axes and angles (forces and moments) are shown by arrows.

Axis.		Force (parallel to axis) symbol.	Moment about axis.			Angle.		Velocities.	
Designation.	Symbol.		Designation.	Symbol.	Positive direction.	Designation.	Symbol.	Linear (component along axis).	Angular.
Longitudinal....	X	X	rolling.....	L	$Y \longrightarrow Z$	roll.....	Φ	u	p
Lateral..........	Y	Y	pitching...	M	$Z \longrightarrow X$	pitch....	Θ	v	q
Normal..........	Z	Z	yawing.....	N	$X \longrightarrow Y$	yaw.....	Ψ	w	r

Absolute coefficients of moment

$$C_l=\frac{L}{q\,b\,S} \quad C_m=\frac{M}{q\,c\,S} \quad C_n=\frac{N}{q\,f\,S}$$

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS.

Diameter, D
Pitch (a) Aerodynamic pitch, p_a
(b) Effective pitch, p_e
(c) Mean geometric pitch, p_g
(d) Virtual pitch, p_v
(e) Standard pitch, p_s
Pitch ratio, p/D
Inflow velocity, V'
Slipstream velocity, V_s

Thrust, T
Torque, Q
Power, P
(If "coefficients" are introduced all units used must be consistent.)
Efficiency $\eta = T\,V/P$
Revolutions per sec., n; per min., N
Effective helix angle $\Phi = \tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS.

1 HP = 76.04 kg. m/sec. = 550 lb. ft/sec.
1 kg. m/sec. = 0.01315 HP
1 mi/hr. = 0.44704 m/sec.
1 m/sec. = 2.23693 mi/hr.

1 lb. = 0.45359 kg.
1 kg. = 2.20462 lb.
1 mi. = 1609.35 m. = 5280 ft.
1 m. = 3.28083 ft.